Aircraft Measurements of $H_2O(v)$, N_2O, CH_4, and CO in support of the Second SAGE III Ozone Loss Validation Experiment

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SOLVE-2 Science Team Meeting

NASA Dryden Flight Research Facility

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Outline of Presentation

- Brief description of DLH and DACOM instruments
- New improvements for SOLVE-2
- Summary of data products, comparisons from SOLVE
- SOLVE objectives supported

DLH: the NASA Langley / Ames Diode Laser Hygrometer

- Tunable diode laser hygrometer operating in the 1.4 μm NIR spectral region
- Wavelength moduation at 4 kHz; 2F detection
- Line-locked to absorption line in low-pressure reference cell
- Uses one of two absorption lines, depending on conditions
- Double-pass external path configuration
  - "mirror" is panel of retroreflecting roadsign material, mounted on the outboard engine
  - sample volume is outside of aircraft boundary layer
  - no inlet effects, such as condensation, evaporation, interaction with walls
  - long path-length (28.5 m on DC-8), combined with line-locked, second harmonic detection allow good sensitivity and rapid time response
- Shares operator and data collection with DACOM instrument

<u>New and Improved for SOLVE-2 !</u>

- Bandwidth improved to 15 Hz
- Improved, automated in-flight calibration procedures
- Preliminary values for water vapor concentration will be reported on the aircraft
- Additional high data-rate, high bandwidth data system added in parallel to existing system

DACOM - Differential Absorption Carbon Monoxide Measurement

- Mid InfraRed diode laser instrument
  - lead salt diode lasers; liquid nitrogen cooled
  - N_2O at 4.5 μm; CH_4 at 7.6 μm; CO at 4.7 μm
- Wavelength moduation at ~10 kHz; 2F detection normalized by chopped DC
- Line-locked to absorption lines in low-pressure reference cell
- Outside air ingested through Rosemont probe, through 36 m, 0.3 liter Herriott cell
- Response time approximately 1 sec
- Periodic in-flight calibration events using calibrated Niwot Ridge air

New and Improved for SOLVE-2 !

- Improved data acquisition system and software
- Equipment weight and size drastically reduced
  - now fits in single rack with DLH

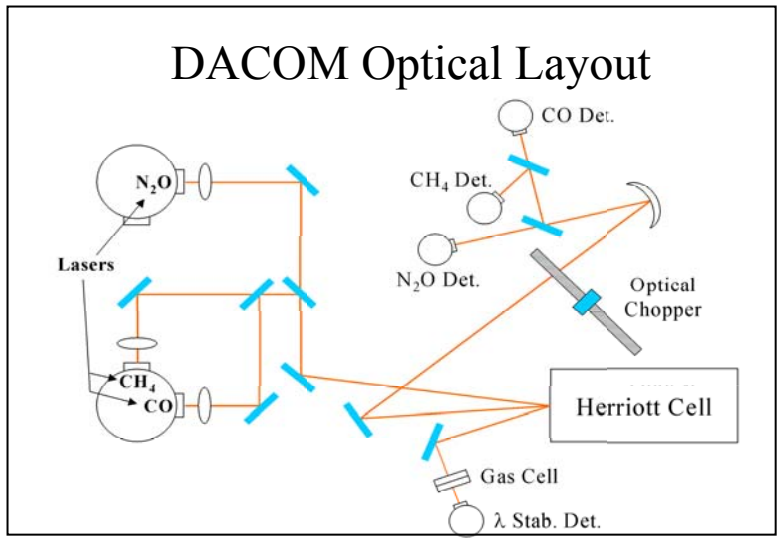
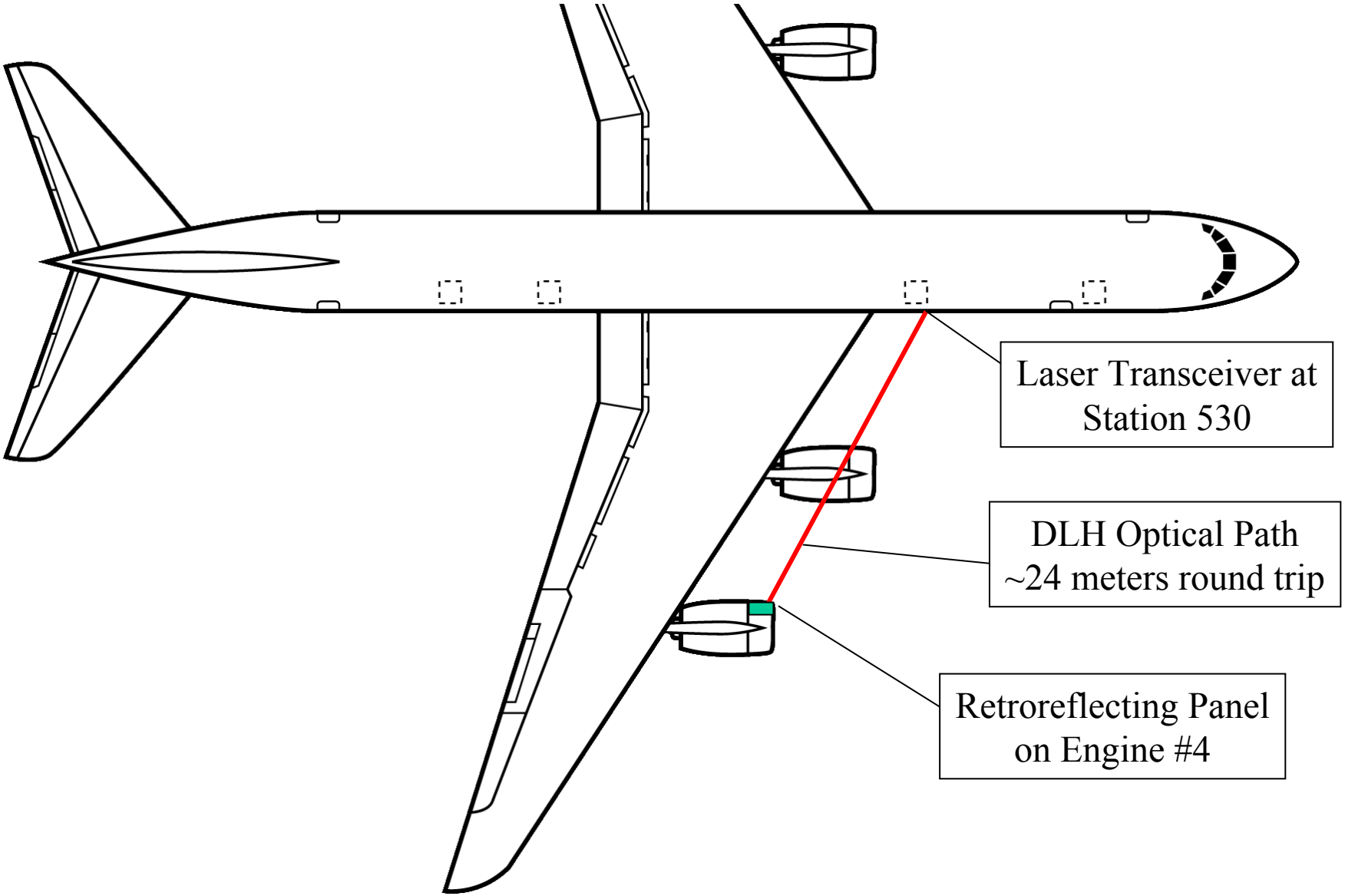


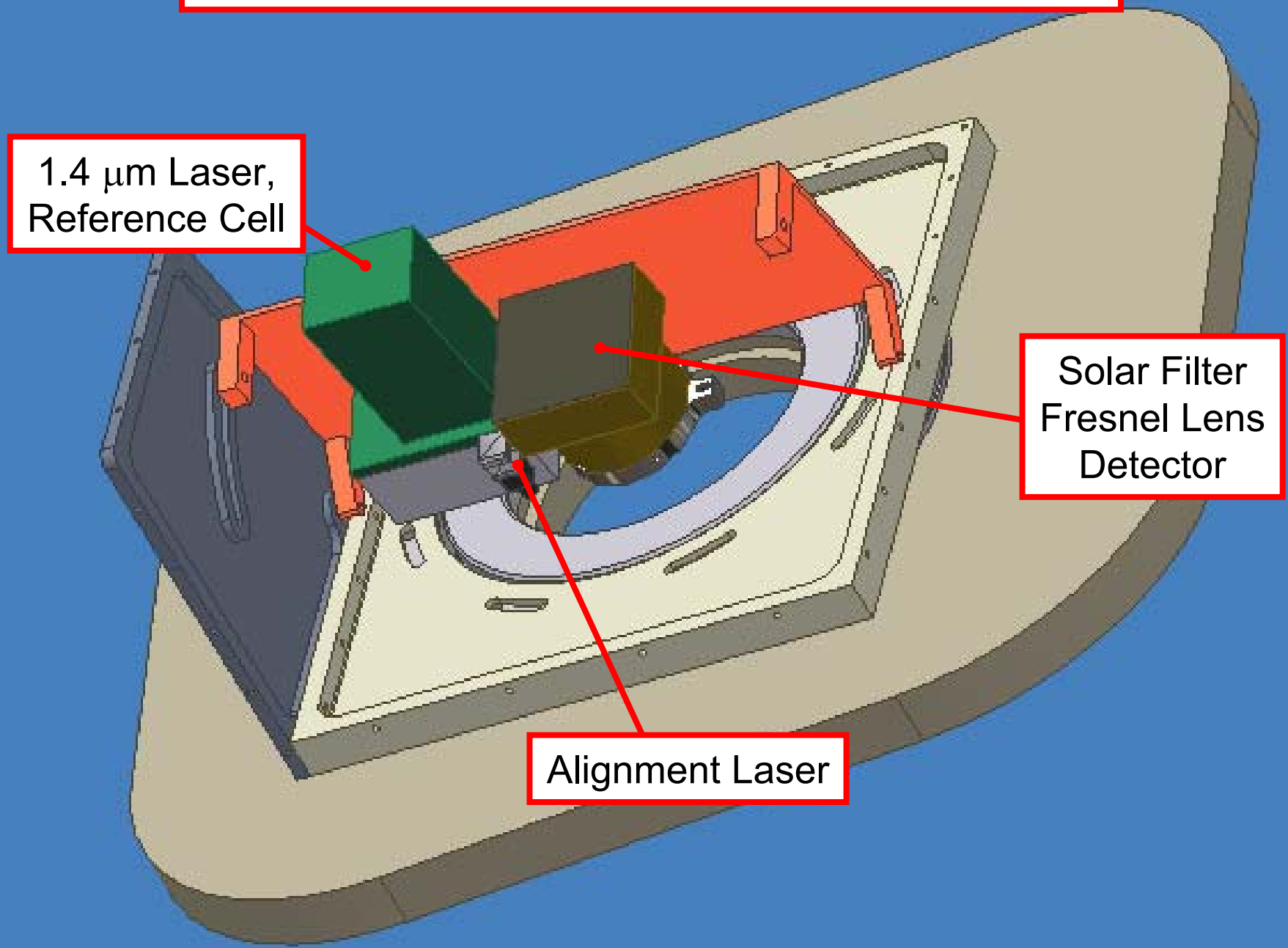
Table 1. Proposed Instrumentation for DC-8

Instrument	Species	Priority	Time Response	Precision (1σ)	Accuracy
Diode Laser Hygrometer	$H_2O(v)$	1	50 msec	1% or 0.1 ppmv	10% or 1 ppmv
Diode Laser In-Situ	N_2O	2	1 sec	0.1%	1%
	CH_4	2	1 sec	0.1%	1%
	CO	2	1 sec	1% or 1ppbv	2%

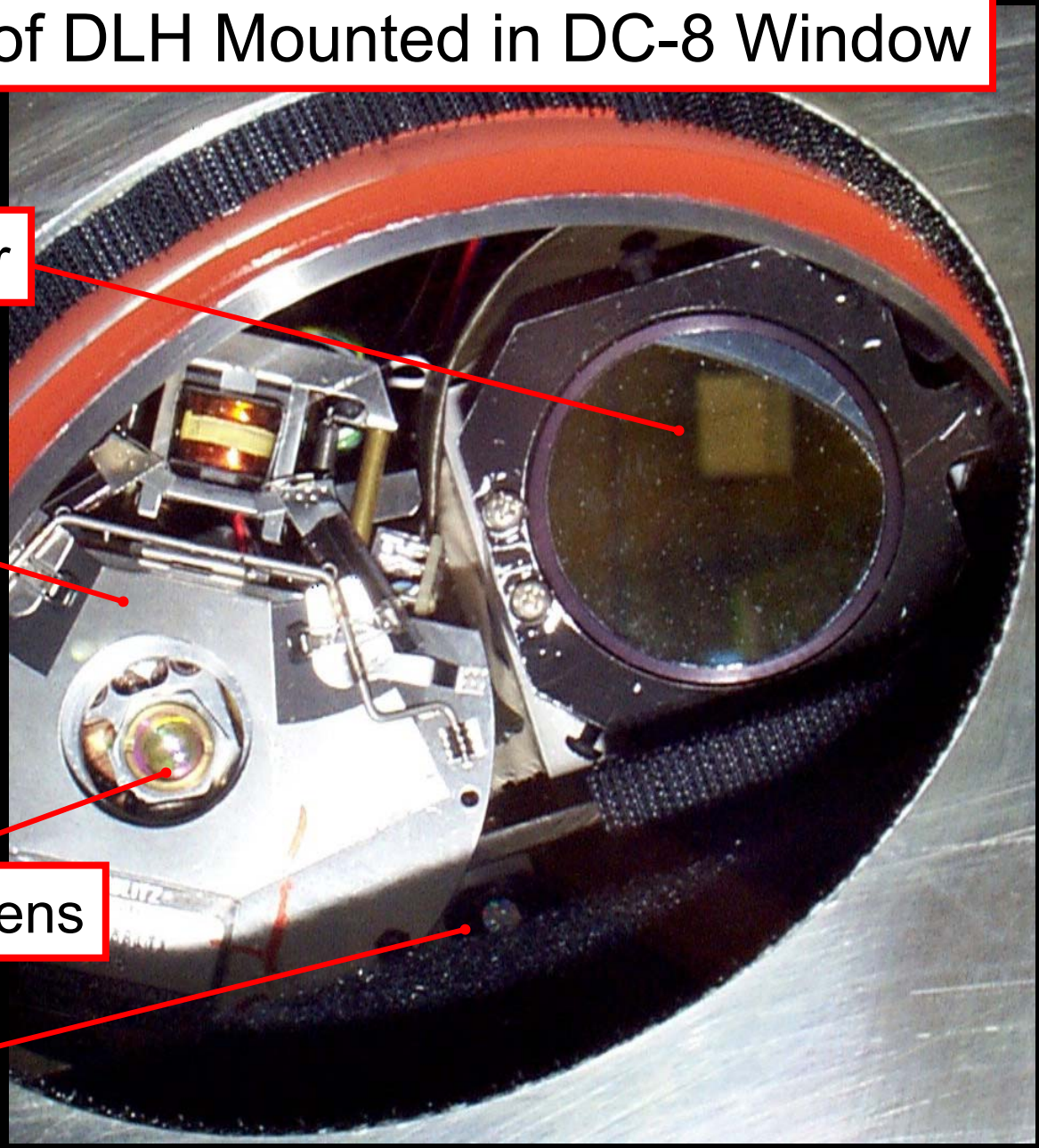
Location of the DLH External Path on the DC-8 Research Aircraft

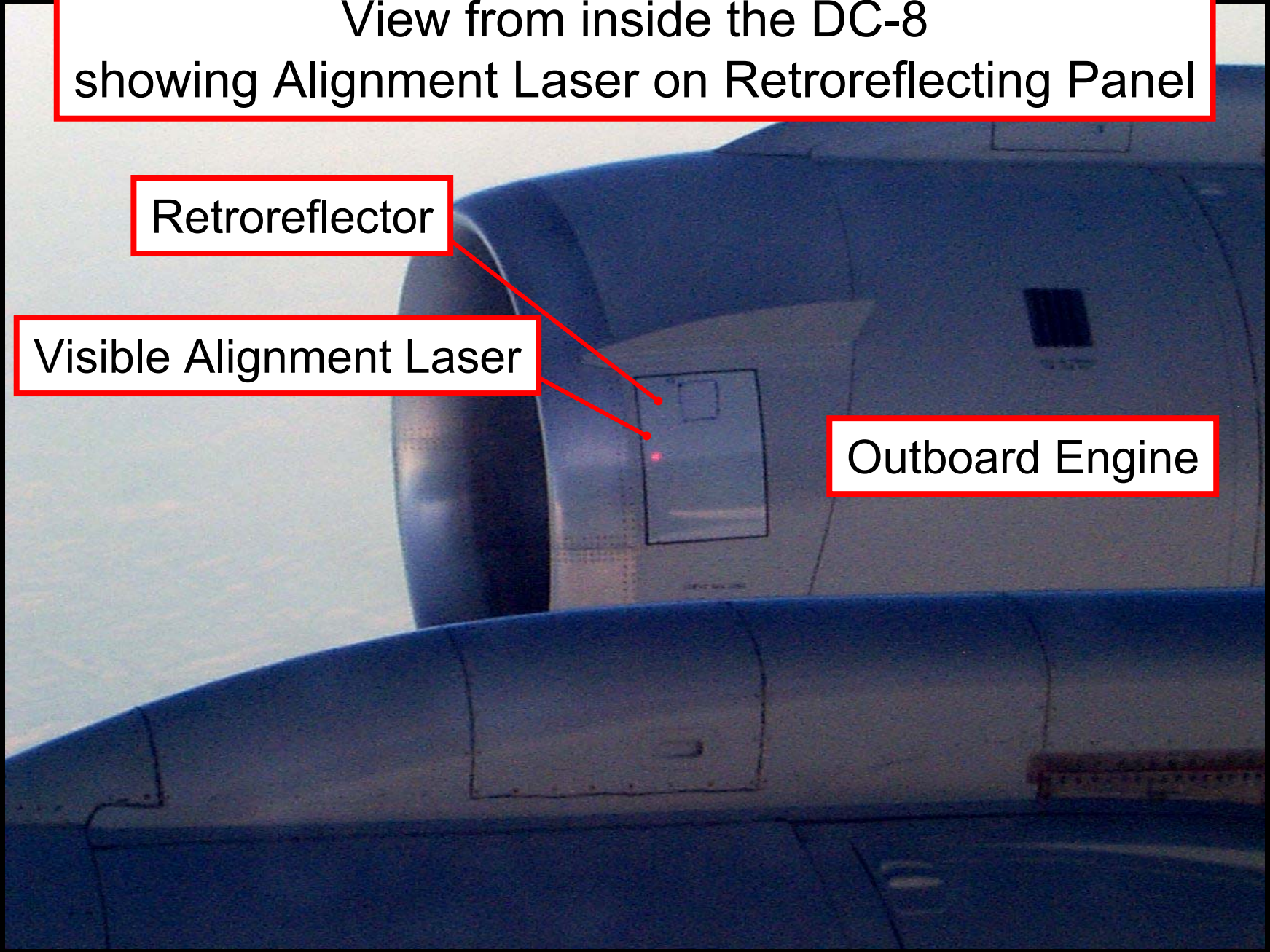


CAD Perspective of DLH Transceiver

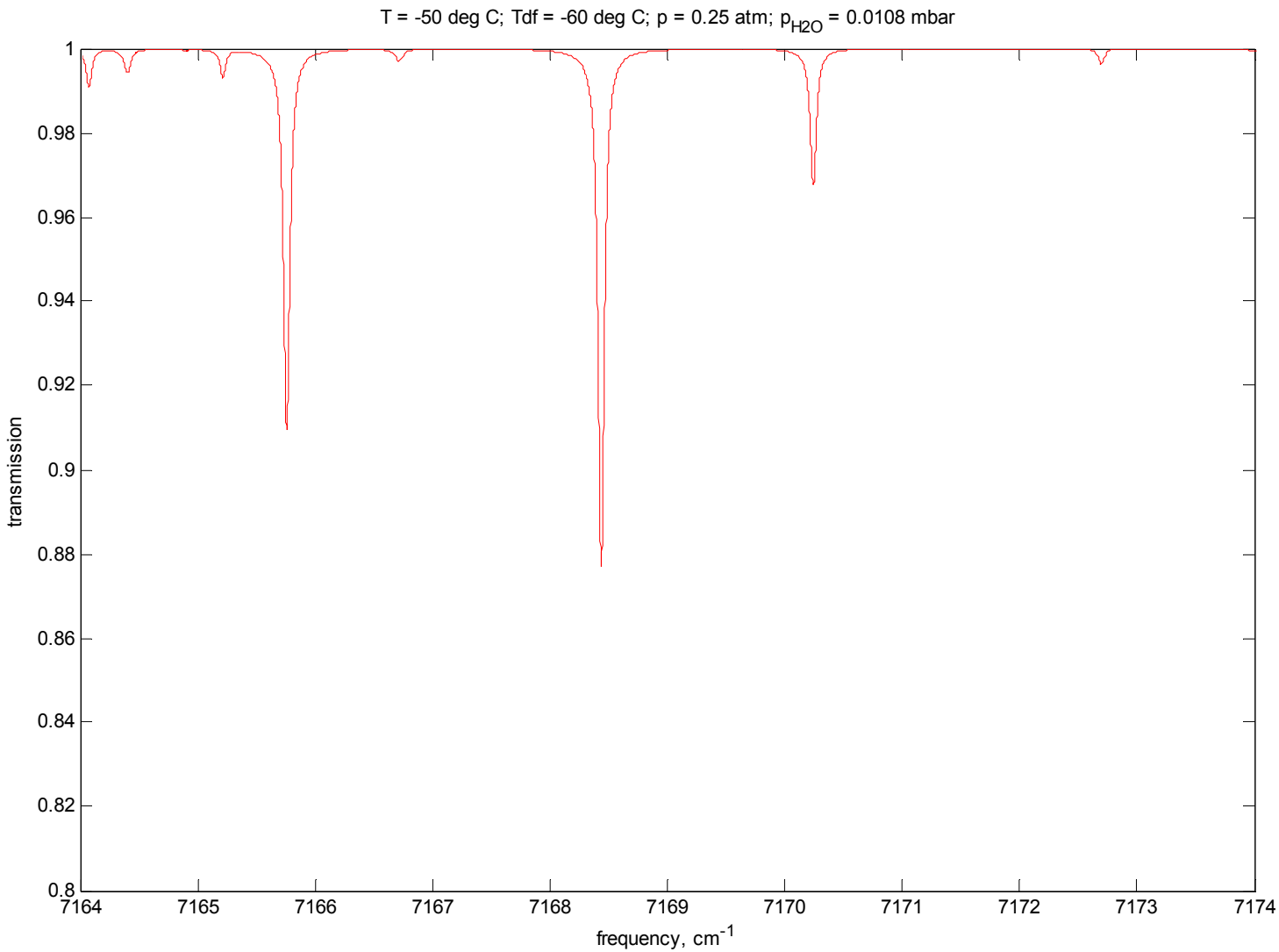


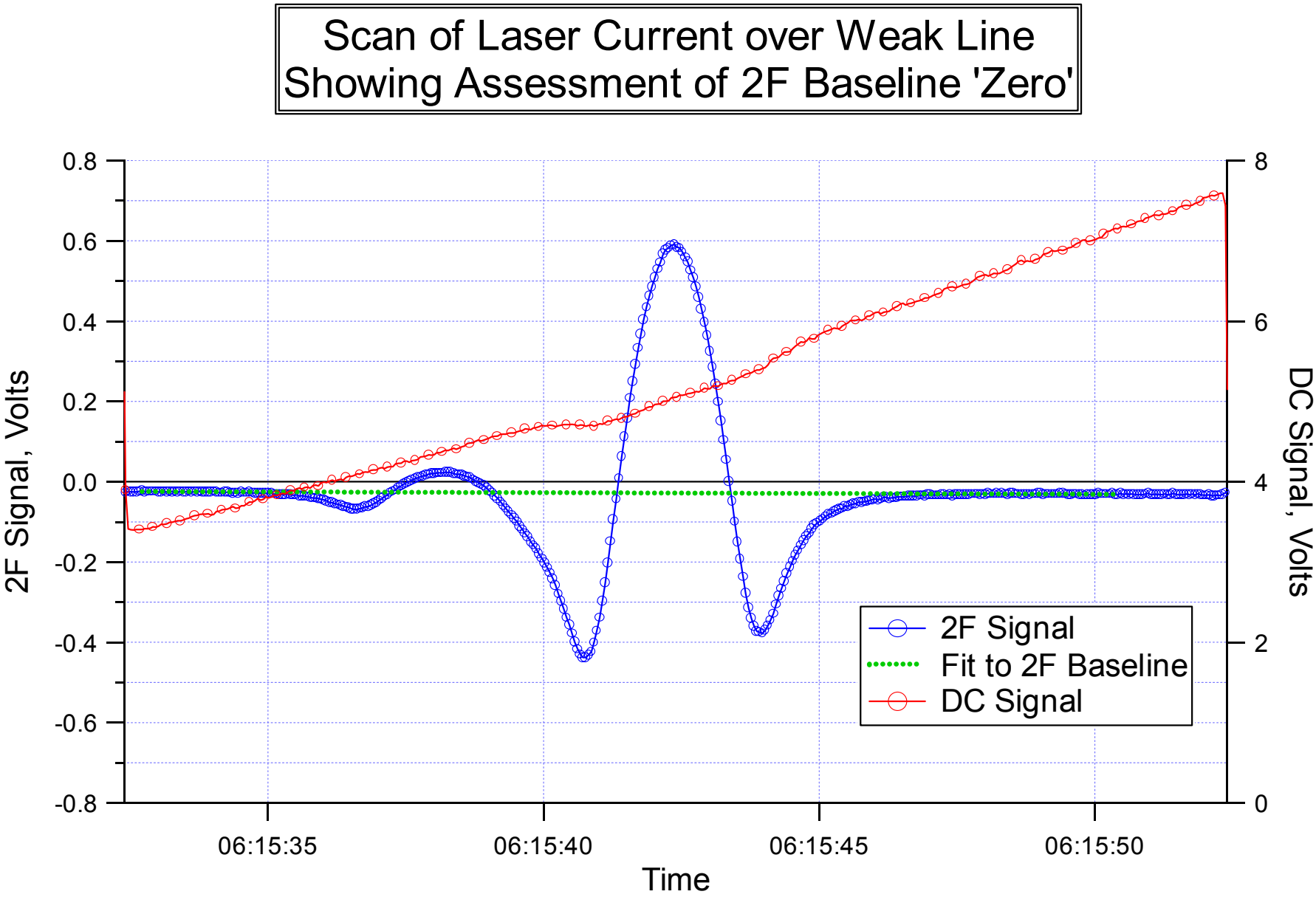
Bird's-Eye View of DLH Mounted in DC-8 Window




View from inside the DC-8
showing Alignment Laser on Retroreflecting Panel
Retroreflector
Visible Alignment Laser
Outboard Engine

Transmission Spectrum in Region of DLH Absorption Lines




Scan of Laser Current over Weak Line
Showing Assessment of 2F Baseline 'Zero'
2F Signal, Volts
DC Signal, Volts
Time
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
8
6
4
2
0
06:15:35
06:15:40
06:15:45
06:15:50
2F Signal
Fit to 2F Baseline
DC Signal

Data Retrieval
- combining calibration with measurements -

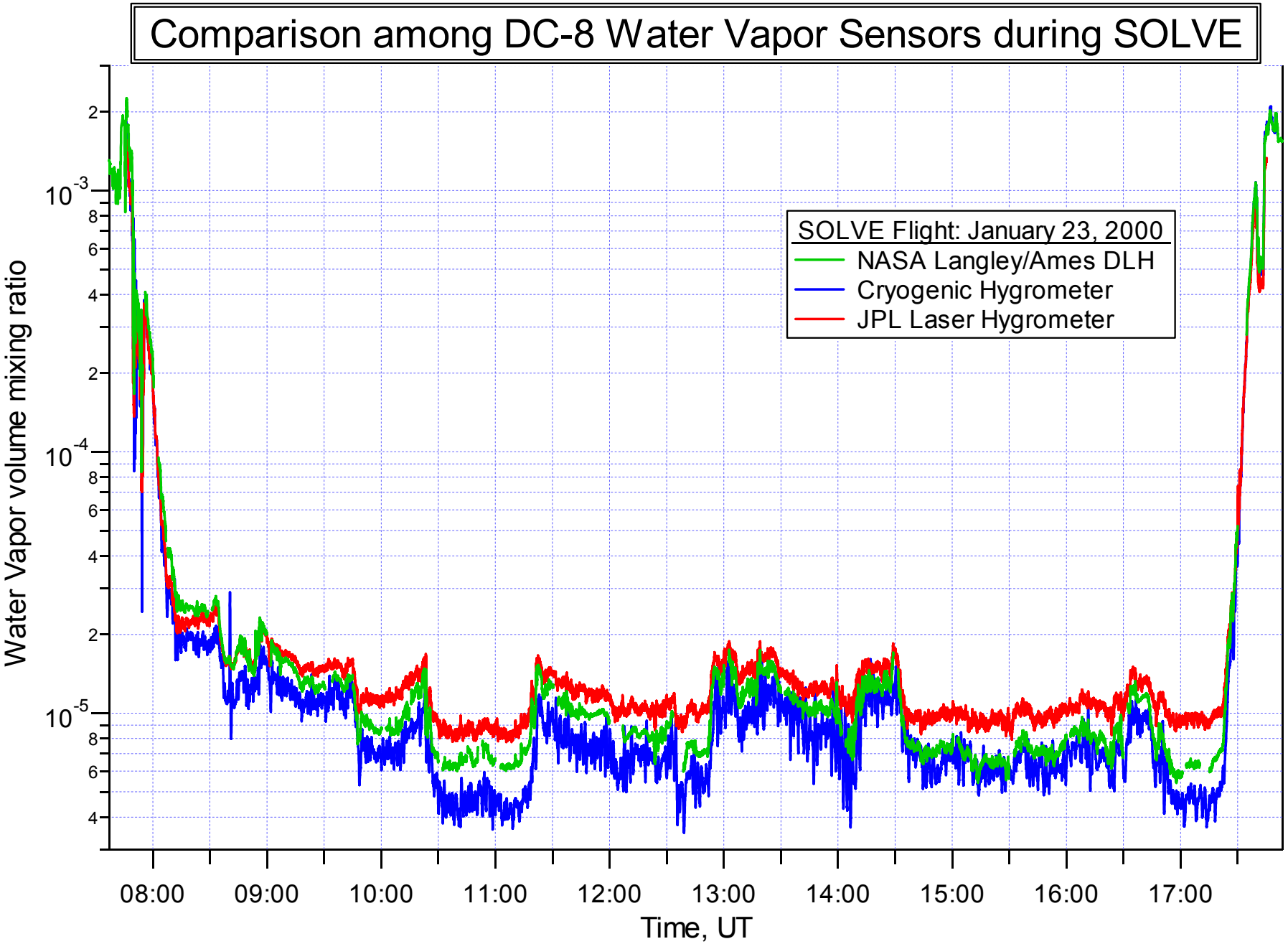
- Calibration Data used to determine linestrength (S) and modulation depth (m)
- Analytical model gives, for a matrix of p, T:

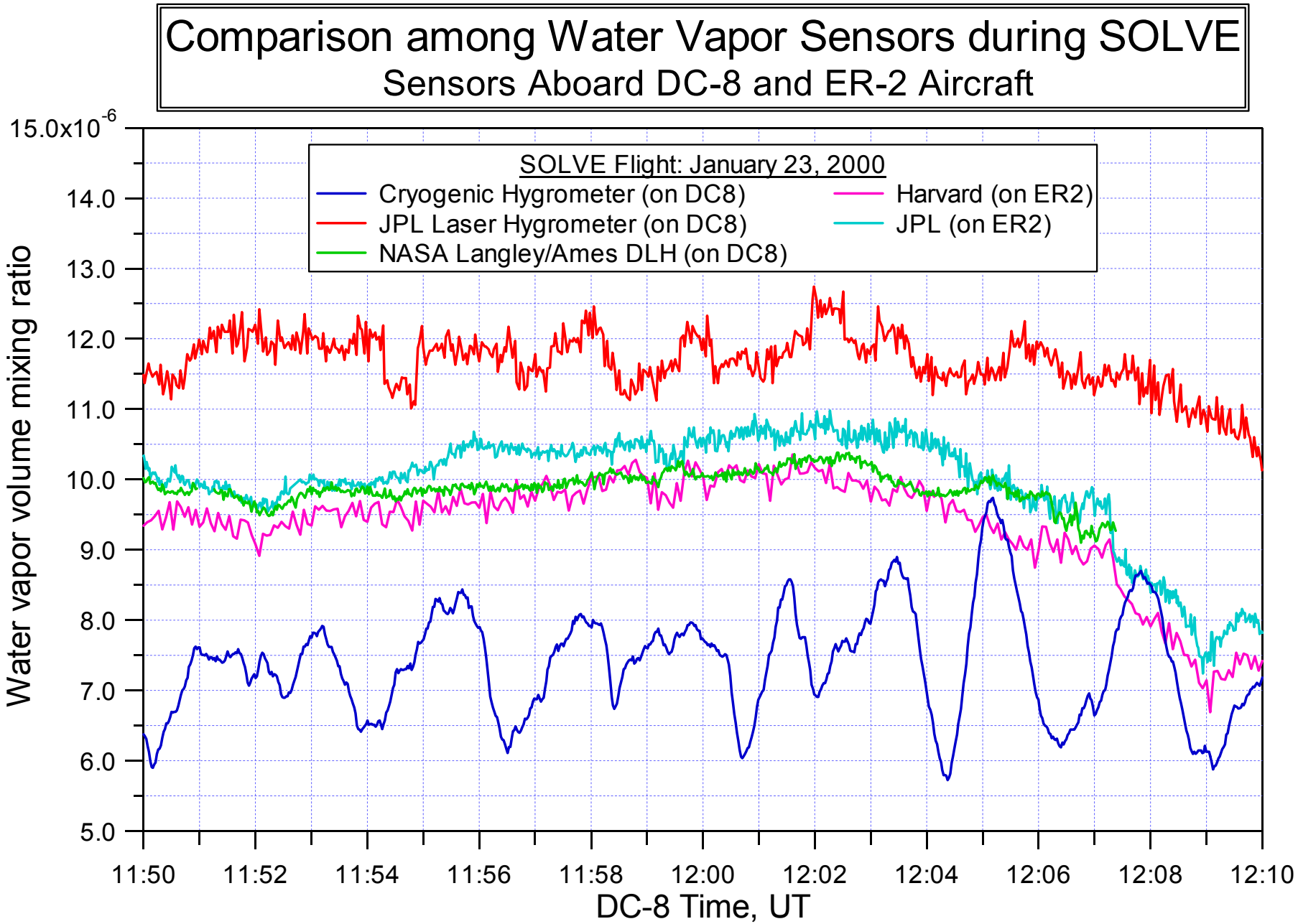
$$2F/DC|_{\lambda_i,\, L} = f_i(\chi[H_2O(v)],\, p,\, T)$$

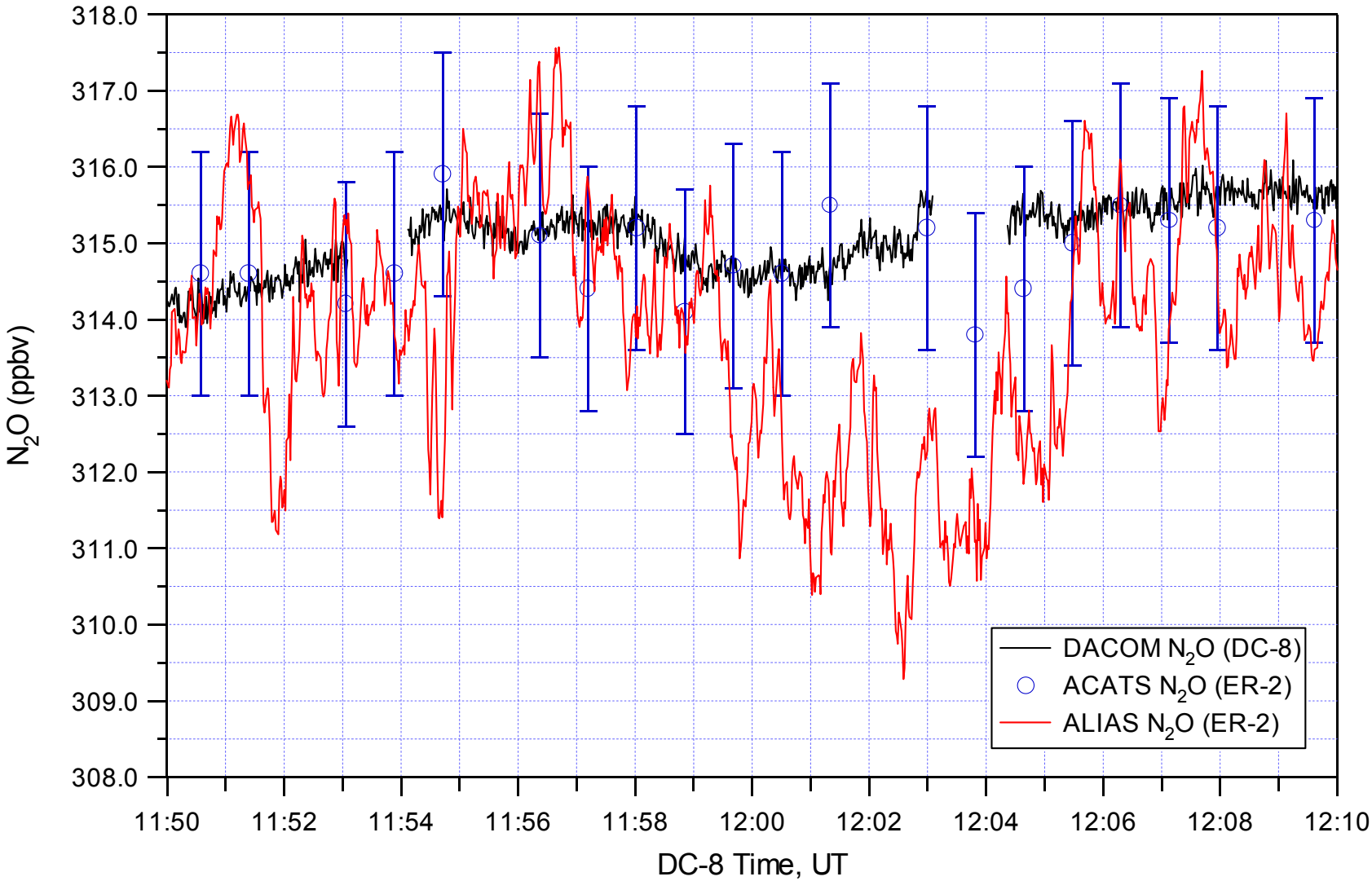
- Polynomial fit to f_i
- Polynomial inverted to give:

$$\chi[H_2O(v)] = g_i(2F/DC,\, p,\, T,\, \lambda_i,\, L)$$

- DLH provides DC, 2F at 20/sec
- Aircraft data system provides p, T at 1/sec
- Measured 2F, DC, p, T combined to yield $\chi[H_2O(v)]$


Comparison among DC-8 Water Vapor Sensors during SOLVE
SOLVE Flight: January 23, 2000
NASA Langley/Ames DLH
Cryogenic Hygrometer
JPL Laser Hygrometer
Water Vapor volume mixing ratio
2
10-3
8
6
4
2
10-4
8
6
4
2
10-5
8
6
4
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Time, UT


Comparison among Water Vapor Sensors during SOLVE
Sensors Aboard DC-8 and ER-2 Aircraft
SOLVE Flight: January 23, 2000
Cryogenic Hygrometer (on DC8)
JPL Laser Hygrometer (on DC8)
NASA Langley/Ames DLH (on DC8)
Harvard (on ER2)
JPL (on ER2)
Water vapor volume mixing ratio
15.0x10-6
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
11:50
11:52
11:54
11:56
11:58
12:00
12:02
12:04
12:06
12:08
12:10
DC-8 Time, UT


318.0
317.0
316.0
315.0
314.0
313.0
312.0
311.0
310.0
309.0
308.0
N2O (ppbv)
11:50
11:52
11:54
11:56
11:58
12:00
12:02
12:04
12:06
12:08
12:10
DC-8 Time, UT
DACOM N2O (DC-8)
ACATS N2O (ER-2)
ALIAS N2O (ER-2)

SOLVE objectives supported

- DLH Water Vapor measurements
  - SAGE-III validation
  - in-situ reference for remote measurements and balloon-borne sensors
  - intercomparison with instruments on Geophysica
  - photochemistry
  - tracer

- DACOM measurements
  - long lived tracers provide information about stratospheric air and thus context in which to interpret other measurements
  - comparison with other instruments on DC-8 and instruments on Geophysica
  - linkage to first SOLVE measurements, historical record

- Both instruments are being downsized and automated with a goal of providing data at lower deployment burden